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Strength Through Science: Using Virtual Technology to Advance the Warfighter

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During any given mission, a warfighter faces demanding information-processing challenges while engaged in intense physical stresses, such as heavy pack loads, extreme temperatures, unfamiliar terrain, and high altitudes. The warfighter must first understand the mission objectives and the information relevant for its successful completion (e.g., the spatial layout of the environment, locations to search, or the appearance and estimated number of enemy combatants or weapons). This abstract information must then be transferred to a live and potentially hostile environment, which can have harsh and unknown conditions. During the course of the mission, the warfighter must maintain vigilance and may be required to identify enemy combatants obscured by unfamiliar and variegated natural environment (e.g., mountain terrain or urban village) and may not be easily distinguished from the noncombatant population. These tasks must also be executed while maintaining a high degree of situational awareness of other physical and cognitive demands.

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Virtual Technology and the Military

Over the last 20 years, technological advances in almost every aspect of combat performance have altered the way the warfighter prepares, approaches, and completes combat-related tasks. Current warfare is a multifaceted engagement, with the warfighter serving as the most complex component of the weapon system. Researchers continually investigate the cognitive and physical stresses of the warfighter and propose actions to improve performance and mitigate injuries. Traditionally, human performance research has struggled to balance testing conditions that emulate the real world with the control and precision of a laboratory setting. This becomes especially difficult in combat-related environments.

In response, military leadership has guided the creation of realistic, operationally relevant training environments outside of theater, such as the Marine Corps Infantry Immersive Trainers. Because field testing of combat operations is generally unfeasible or at least logistically challenging, immersive environments provide a fitting alternative for scientists to study the warfighter. To further bring the field into the laboratory, virtual technology has emerged as a leading tool to define the experiences of warfighters during combat-type operations (1).

The military has a long history of using virtual reality for training. As early as 1910, the aviation community operated simplistic ground-based flight simulators to train pilots, with the Link Flight Trainer (Link Aviation Devices Inc., Binghamton, NY), becoming one of the most widely used during World War II (3,6). Driving simulators like the Common Driver Trainer (Science Applications International Corporation, McLean, VA) are currently used to train warfighters to maneuver military vehicles in unfamiliar terrain (e.g., mine-resistant ambush-protected vehicles through Afghanistan) without damage to vehicles or personnel. As technology advanced, these simulators, like the Comet IV simulator (Redifon, Crawley, UK) included haptic (force) feedback on the controls and platforms that produced pitch, yaw, and roll motions. However, simulation of infantry-type tasks, when the warfighter has "boots on the ground," dramatically increases the complexity of an immersive environment. During human movement, the brain subtly registers visual, auditory, and tactile inputs regarding the position of the person as he or she progresses. These subtle cues are difficult to replicate in a controlled laboratory setting. Fortunately, the exponential growth of technology in the last decade has evolved virtual reality and immersive applications for medicine and research. Visual display synchronization and hardware control innovations, largely from the commercial video-gaming industry, have made immersion in virtual environments extremely realistic to the user.

The Warfighter Performance Laboratory at the Naval Health Research Center (NHRC) in San Diego, CA, has installed a state-of-the-art tool called the Physical and Cognitive Operational Research Environment (PhyCORE) that has as its base a Computer Assisted Rehabilitation Environment (CAREN) Extended System (Motek Medical Inc., Amsterdam, Netherlands; http://www.motekmedical.com/products/caren/). The PhyCORE is a unique tool that provides an immersive and interactive experience in which the subject responds in real time to visual, auditory, vestibular, and tactile inputs (**Fig. 1**). While traditional testing equipment is limited to the examination of individual aspects of human performance (usually cognitive or physical only), the PhyCORE engages multiple sensory systems and has versatile utility for diagnostics, rehabilitation, and research.

System Capabilities

Currently, there are four different CAREN systems within the United States Department of Defense (NHRC, Walter Reed National Military Medical Center, Center for the Intrepid, and National Intrepid Center of Excellence) and approximately 20 others in the world. The systems are primarily used for rehabilitation of patients with complex injuries. At NHRC, we have expanded the capabilities to meet the technical and operational demands of addressing clinical and performance research questions. Using the PhyCORE, researchers measure and analyze balance, posture, gait, motor learning, vigilance, response time, and decision making. Hardware, including a synchronized scent system (ScentAir, Charlotte, NC), wireless controllers, and weighted airsoft weapons, have been added to improve the overall immersion experience. Wireless electromyography, accelerometers, EKG, and force transducers (Delsys Inc., Boston, MA) have also been incorporated for further data acquisition and novel control mechanisms.

By integrating virtual reality principles with traditional testing constraints, the PhyCORE provides a realistic environment for controlled and repeatable experiments. The PhyCORE occupies approximately 2,000 ft^2 of the Warfighter Performance Lab located at the Naval Third Fleet Complex in San Diego, CA. A majority of the system resides within a cylindrical concrete pit (5 ft deep × 14.5 ft in diameter) in the laboratory floor. A circular platform (9 ft diameter) is situated atop a motion base secured to the foundation of the pit. Four electrical actuators linearly move this platform up to 16" in the fore, aft, and lateral directions, up to 7" in the vertical direction, and up to 20° around each rotational axis (pitch, yaw, and roll). A dual-belt (side by side) treadmill with instrumented force plates are integrated into the moveable platform. The pit is surrounded (180°) by a 9 ft tall curved screen which displays the environment generated from three projectors. This graphical environment is synchronized with the movement of the platform and treadmill. Surrounding the system are 12 optical motion capture cameras (Motion Analysis Corporation, Santa Rosa, CA). Retroreflective markers can be placed on anatomical landmarks and/or objects (e.g., a handheld weapon). Traditionally, motion capture is used to collect positional data of body segments and joint rotations during normal movement. In the PhyCORE, the motion capture system and CAREN D-flow software further process positional data points for real-time system interaction.

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Fig. 1. The Physical and Cognitive Operational Research Environment (PhyCORE), which provides an interactive, immersive environment for use in diagnostics, rehabilitation, and research.

The CAREN system comes standard with several basic applications that can be used for a variety of patient populations, but custom applications can also be created for specific purposes or interventions. One of the more popular standard programs, the "Boat" scenario, requires the user to pilot a virtual boat through a marine slalom course. This course consists of numbered buoys, virtual sharks, and landmasses that must be avoided and properly circumnavigated. During the course, the platform moves in synch with the motion of the boat on the waves. The interaction can be varied depending on user ability or familiarization level. Alterations in maximum boat speed (movement through the scene), turning sensitivity (platform rotations), wave height (vertical platform displacement), wave speed (platform rotation/displacement frequency), and obstacles are adjusted before or during the course by the system operator. This scenario has been used at NHRC as part of a research program to measure learning ability of able-bodied subjects in this environment, and for a group of patients using this as part of a vestibular rehabilitation program.

Additional programs include "Endless Road" and "City Street" scenarios, where users walk on the treadmill through a rural outdoor path or a typical city street, respectively. We have used the Endless Road scene as part of our vestibular rehabilitation program in traumatic brain-injured patients. At random intervals and locations, simple math problems or other cognitive tasks are displayed to force patients to rotate their head and scan their visual field while walking. In the City Street program, the goal is to avoid common obstacles, such as street signs, moving vehicles, and pedestrians. The complexity of the scene can range from a simple sidewalk, a few buildings, and a few pedestrians to a complex urban atmosphere with large skyscrapers, crowds of pedestrians, and city traffic.

Using each of these commercial rehabilitation programs as models, we developed a mountain terrain (virtual Afghanistan) similar to the environmental experience of recent conflicts. The program is synchronized with the treadmill and motion platform to reflect changes in terrain (incline, decline, slant) and immerse the warfighter. We have added operational objects to the program, such as military vehicles, air support, equipment, and hazards (e.g., improvised explosive devices). As the warfighter progresses through the environment, combatants and noncombatants appear in the landscape and the warfighter must appropriately target and shoot the combatant using the integrated weapons system. This program is similar to commonly used commercial first-person shooting games. Currently, this program is used as part of our vestibular rehabilitation study and it will also be used to examine the combined physical (e.g., heavy carriage loads, hypoxia) and cognitive stresses (decision making, memory) experienced by infantry warfighters.

Research

We are establishing the reference and standards for movement, learning, and adaptations within the immersive system. Previous research has shown spatiotemporal differences in the way people move over ground vs. on a traditional treadmill (2,4,5). The lack of proprioceptive and visual cues on a treadmill cause subtle differences in the response of the individual (e.g., slower preferred walking speeds, altered foot–ground contact). These differences become relevant when attempting to explore the effects of diverse physical and cognitive military protocols. The PhyCORE addresses this by providing realistic optic flow and feedback synchronized with the movement of the treadmill and motion platform.

We are currently examining the spatiotemporal characteristics of normal walking in the PhyCORE. We hypothesize that immersive environments will significantly reduce the differences observed during walking on a traditional treadmill compared with overground terrain. Further, we have developed realistic scenarios to reflect current operational missions. With these, we can measure cognitive performance with tasks such as memory recall, reaction time, target/no target, and navigation. While operating in this scenario, the warfighter can be outfitted with the current standard tactical gear, uniform, and weighted mock weapons. This provides the ability to address difficult operational research questions by monitoring physiological, cognitive, and performance metrics difficult to collect in field settings.

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To prepare and protect the modern warfighter requires understanding three facets of human research: how do we reset the injured, enhance performance, and facilitate resilience? Virtual environment technology will enable development in all three facets in both the physical and cognitive domains. The current expansion of NHRC's PhyCORE system has increased our ability to analyze realistic, operationally relevant tasks with the validity of a research laboratory environment. Integration of video-gaming technology, artificial intelligence, and established measurement devices will expand the system into a complete warfighter assessment tool. As we foster the ability to demonstrate pertinent warfighter tasks in the laboratory, we will enhance our ability to proactively prevent injury and increase the strength of our warfighting community.

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14. ABSTRACT

The Computer Assisted Rehabilitation Environment (CAREN) is an emerging, cutting-edge, rehabilitation and research tool for our warfighters, but its capabilities and treatment effectiveness have not been fully determined. This article gives an overview of the purpose and usefulness of the CAREN at Naval Health Research Center.

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